ON THE DISTRIBUTION OF RADIO BRIGHTNESS ON THE QUIET SOLAR DISK AT 4,000 MC/s.

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Summary— An 8 element interferometer with quarter-wavelength plates operating at 4,000 MC has been constructed and observations have been carried out since June 1954.

The daily drift curves from June 1954 to June 1955 were superimposed at intervals of about one month and E-W one dimensional brightness distributions on the quiet sun were calculated from the lower envelopes of these curves.

If circular symmetry is assumed, the derived radial brightness distributions show limb-brightening.

I. Introduction

For research of the temperature and density distribution in the solar atmosphere, measurements of the brightness distribution must be taken at various frequencies.

To date, in the cm-dm range of wavelengths, one-dimensional brightness distributions have been measured by Christiansen and Warburton with 32 element interferometer at a wavelength of 21 cm[1] and by Covington and Broten with a linear array at 10. 3 cm.[2] The derived radial brightness distributions show very marked limb-brightening.

In 1953, an interferometer with 5 aerials operating at 4, 000 MC was constructed at Toyokawa and reconstructed in 1954 into an 8 element interferometer with quarter-wavelength plates. Observations by the latter have been carried out since June 1954.

The main lobes are spaced 40′ apart having a half-power width of 4. 5′.

The daily records were superimposed and E-W one-dimensional distributions were calculated from the lower envelopes of these curves.[1]

If circular symmetry of the solar disk is assumed, the calculated radial brightness distributions show limb-brightening.

II. Observational Data

The observation is carried out every day over a period of about one-half hour around the local noon. As described on page108, about five drift curves for each of the right-hand and left-hand circularly polarized components of the radiation are obtained.

The recording meter is of 10 mA and rectangular coordinate type with a time scale of 15 mm per minute. To improve the accuracy of the measurement, the receiver is calibrated every day by means of a hot load (about 300°C). A square-law detector and a linear output amplifier are used in the receiver. The r. m. s. noise fluctuation on the receiver output is about 1 °K.

Time marks are made by a clock every one minute on the daily records and this clock is adjusted to indicate the local time. Then the position of the optical sun with respect to an aerial beam can be easily found.

In order to diminish the effect of noise fluctuation, the drift curves for r. h. circularly polarized components are superimposed; the drift curves for 1. h. circularly polarized components are superimposed also. Each result is averaged separately.

To compare these averaged daily drift curves with each other, two corrections are made. The first is for the changing scanning velocity[3], (the change in the width of a drift curve). Since the width of a drift curve corresponds to 40 min. arc. (beam spacing), the record time scale is divided into intervals corresponding to 1 min. arc. and the ordinate of each point is read off.

The second is for the changes in the receiver gain and the transmission loss of the feeder. Because the hot load is used for daily calibration of the radiometer and because the zenith temperature, which is the equivalent antenna temperature measured at the input of the radiometer when all aerials are directed toward the zenith, is recorded every day, these changes can be easily detected. The zenith temperature varies with the atmospheric temperature. The sky temperature, the reference level of the record, is a little higher than the zenith temperature due to the radiation from the ground.

The daily area of the drift curve must be proportional to the daily flux at 3750 MC/s. Therefore, if the ratio of the area to the flux is calculated every day, the change in the gain of the system can be found. [1]

In order to find the drift curve corresponding to the quiet sun, daily drift curves were superimposed and the lower envelope was traced, as described by W. N. Christiansen[1].

When the daily records are superimposed, the effect of the change in the apparent size of the sun andh' te change in the inclination of the sun's axis must be taken into account. But as these changes during one month are very small, the daily drift curves were superimposed at intervals of about a month.

When the lower envelope was traced, the average of the lowest points consistent within the accidental error (±3° K) was taken.

The lower envelopes are shown in Fig. 1. They are symmetrical about their center and are similar in shape. The difference between r. h. and l. h. circular polarized components was not found,

In 1954, the sun was almost quiet and sometimes the drift curves nearly consistent

Fig. 1. Drift curves corresponding to the quiet sun.

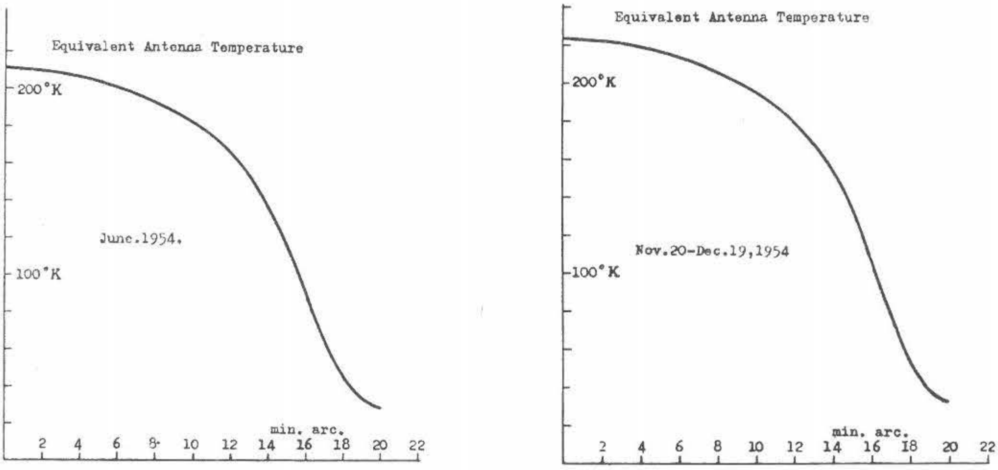

Fig. 1. (1)

Fig. 1. (2)

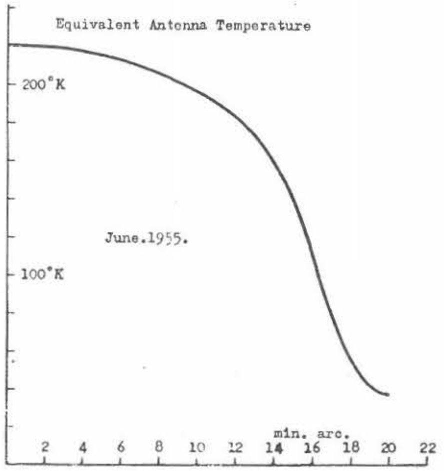

Fig. 1. (3)

with the lower envelope were obtained. Particularly, from 10 to 14 June 1954, the sun was comparatively quiet and the drift curves of those days were symmetrical and unchanged. The curve of June 1954 in Fig. 1. is not the lower envelope, but is the average curve of the drift curves of those days.

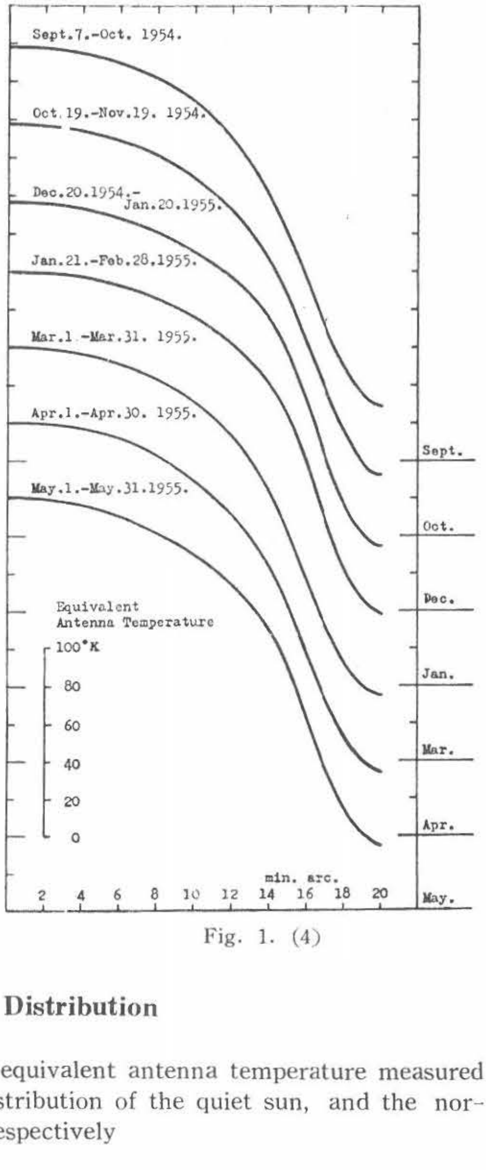

Fig. 1. (4)

III. Brightness Distribution

Assume that T_a, $D(\theta)$, $f(\theta)$ denotes the equivalent antenna temperature measured from the sky level, E-W one-dimensional distribution of the quiet sun, and the normalized power pattern of the aerial system, respectively

$$T_a(\chi)=\frac{GL}{4\pi}\int f(\theta)D(\theta-\chi)\ d\theta$$

where G $(=1920\times 8)$ is the maximum gain of the aerial system. L $(=0.608)$ is the coefficient of the transmission loss of the feeder$^{1)}$ and χ is the angle between the direction of the maximum of the antenna pattern $(\theta=0)$ and the center of the sun. The normalized power pattern of one element can be set to unity over the solar disk. Then $f(\theta)=\frac{1}{64}\ \frac{\sin^2\ (8\pi l\sin\theta/\lambda)}{\sin^2\ (\pi l\sin\theta/\lambda)}$.

The experimental pattern was checked by comparing the theoretical pattern with the record for the radio spot, which is the excess over the lower envelope. The records having a halfpower width of 4.7′ have been obtained at times, a value nearly equal to

Fig. 2. E-W one dimensional brightness distributions.

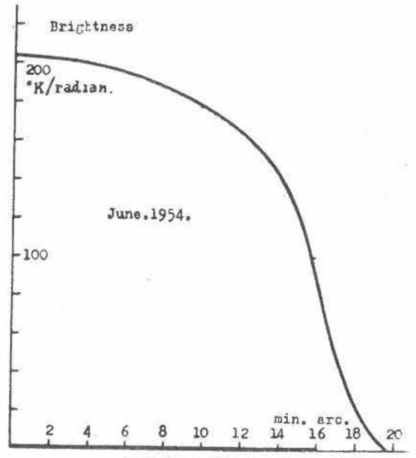

Fig. 2. (1)

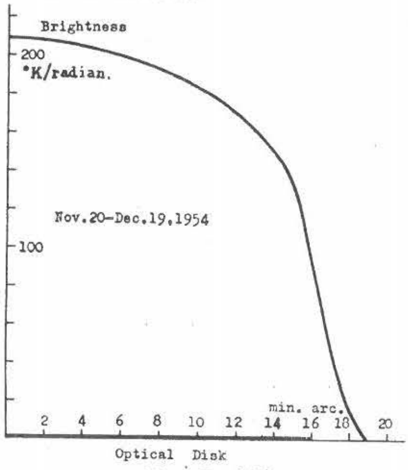

Fig. 2. (2)

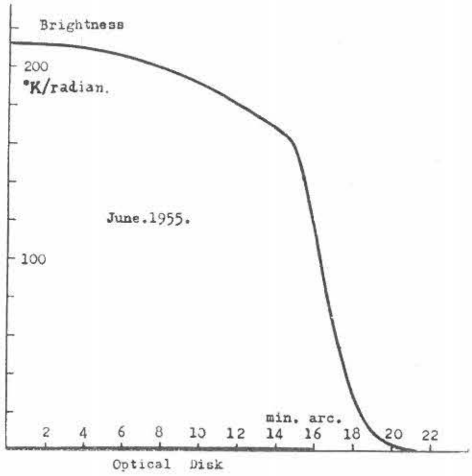

Fig. 2. (3)

the calculated value and the observed half-power width 5.2′ of the "strong radio spot" in June 1955 is quite reasonable when referred to the model of the spot (p. 87).

The solution of the above equation was found by successive approximation5). T_a was used as the first approximation; then scanned with the aerial pattern and the result compared with T_a. The difference between the reconstructed curve and T_a was used to make further approximation. This process was continued until the

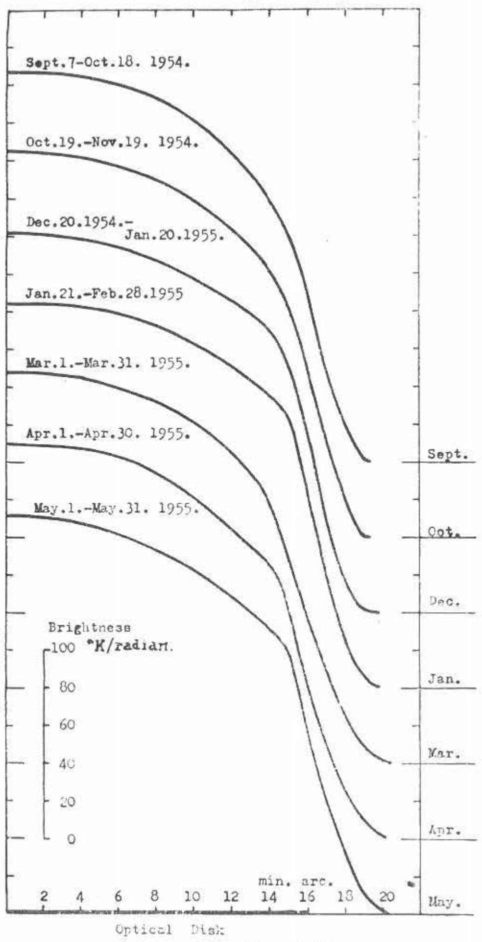

Fig. 2. (4)

reconstructed curve agreed with T_a within the accidental error.

As it is impossible to resolve the fluctuations of the true distribution which have an angular width much less than the beam width, each approximation was adjusted in such a way that the over-all curve was smooth.

Finally, the correction for the change in apparent size of the sun was applied to the result, i. e. each solution was expanded or contracted both in height and width by the sun's distance on the day midway in that period.

E-W distributions are shown in Fig. 2. They are similar in shape. The width of the radio sun in E-W direction at this frequency is about 1. 2 times that of the optical disk.

The quiet sun emission increases gradually in company with sunspot activity. The apparent disk temperature is 2.5×10^4 °K in June 1954, 2.6×10^4 °K in December 1954 and 2.8×10^4 °K in June 1955.

If circular symmetry is assumed, the radial brightness distribution can be calculated from E-W one-dimensional distribution. Three derived radial distributions are given in Fig. 3 and they show limb-brightening. The radial distributions of other months are similar. The effective temperature of the center of the radio disk is about 1.8×10^4 ° K.

As described on page84, the result of the eclipse observation, June 20 1955, has shown that the assumption of circular symmetry is incorrect and that it is preferable to assume an equatorial belt. Recently, Christiansen and Warburton constructed N-S interferometer and have shown that the radio sun is markedly asymmetrical.

IV. Acknowledgement

The auther wishes to express his appreciation to Dr. H. Tanaka for his valuable discussions and suggestions.

Fig. 3. Radial brightness distributions.

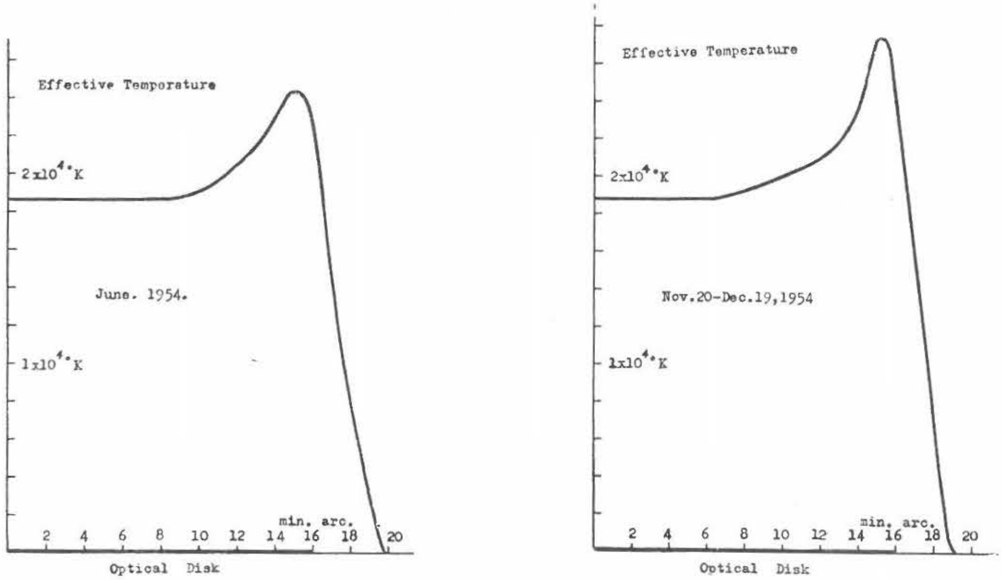

Fig. 3. (1)

Fig. 3. (2)

References

(1) W. N. Christiansen and J. A. Warburton: Aust. J. Phys. vol. 6, p. 262, 1953.

(2) A. E. Covington and N. W. Broten: Astrophys. J. vol. 119, p. 569, 1954.

(3) H. Tanaka and T. Kakinuma: Proc. Res. Inst. Atmos. vol. 2, p. 63, 1954.

(4) H. Tanaka and T. Kakinuma: p. 104 in these Proceedings.

(5) J. G. Bolton and K. C. Westfold: Aust. J. Sci. Res. A. 3, p. 19. 1950.

(6) U. R. S. I. Special Report, No. 4, p. 25, 1954.

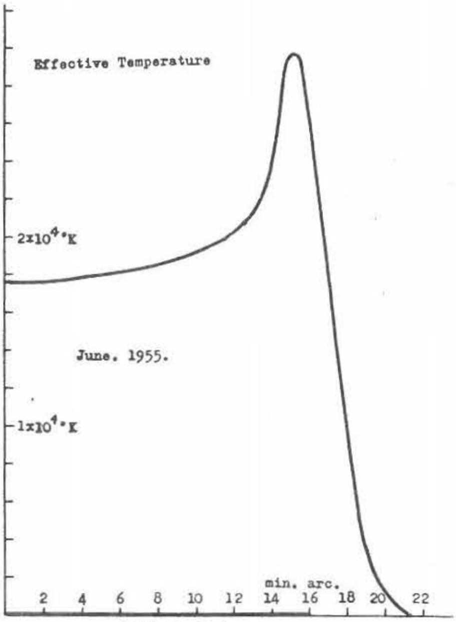

Fig. 3. (3)